Analysis of the Distribution of Ice Rafted Debris in a Northwest Pacific Deep-Sea Core and Comparison with Adjacent Investigations

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INTRODUCTION

This paper concentrates on a single sedimentary core sampled from the northwest Pacific. The core was drilled at Site 580 northeast of Japan (Fig. 1) by the Deep Sea Drilling Project in June, 1982. It extends 153 meters below the sea floor and spans 3.3 million years. The purpose of this study is to measure amounts of glacial ice rafted sediments from the samples and determine how they correlate with other data that helps delineate the time and extent of continental glaciations and climatic changes.

Conolly and Ewing (1970) suggest that the presence of large grains (>.5mm) in the deep ocean are evidence for glacial ice rafting as a transport mechanism. The sources for terrigenous sediments at Site 580 are probably Kamchatka, Siberia, and possibly Alaska and Canada. The barriers of the Kuril trench to the northwest, the Aleutian trench to the north, and sea floor topographic highs to the east would prohibit transport of sand size grains by turbidity flows (Horn et al., 1969). While it is assumed that finer grained sediments are also ice rafted, this study considers only the >250μ size fraction of the samples.

During colder periods of the Pleistocene, continental glaciers calved off and floated out to sea. As they melted, erratics would drop onto the sea floor. Ablation would concentrate debris at the surface of the icebergs, and overturning due to unstability or collision could dump a large accumulation into one area (vón Huene et al., 1973). The rate of accumulation of Ice Rafted Debris (IRD) at any given spot in time then is dependent on: (1) glacial advance, (2) proximity to the glacier, (3) rate of melting, (4) quantity, size, and distribution of erratics contained in the ice, (5) wind and marine currents, and (6) random events such as iceberg collisions and overturning.

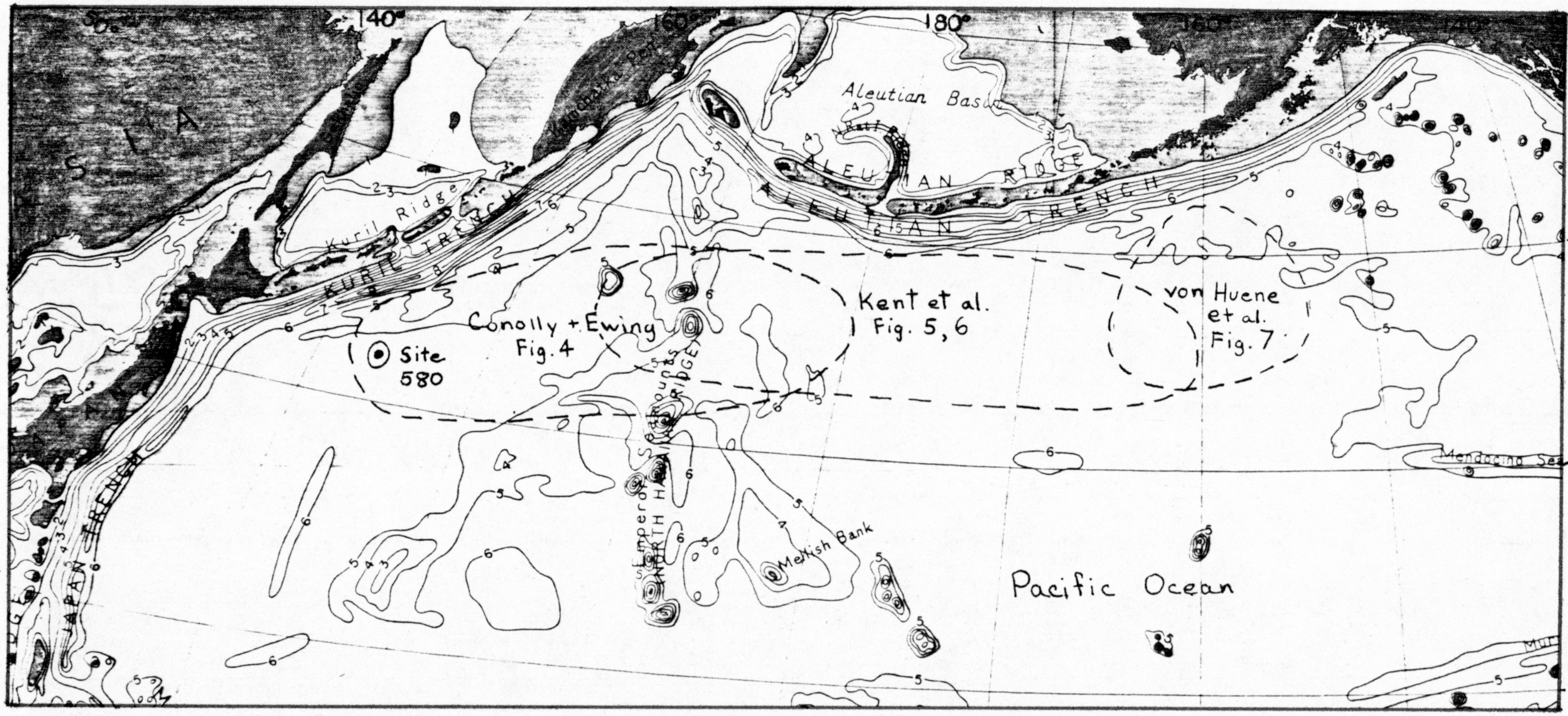


Figure 1. Location of DSPD Site 580

Dashed lines show areas where data is compared (for more detail see inset maps in figures).

SAMPLE ANALYSIS

The $>250\mu$ sediment fraction at Site 580 was divided into four main components for analysis: ice rafted debris, volcanic lithic fragments, volcanic glass and pumice (ash), and biogenic components. Pelagic inorganic precipitants (ferro-magnesium micronodules) were considered separately, but are grouped with the biogenic components in a comparative graph (Fig. 2B). The nodules are rare except in a few samples. The biogenic constituents are mainly radiolarians, with lesser quantities of diatoms and foraminifera.

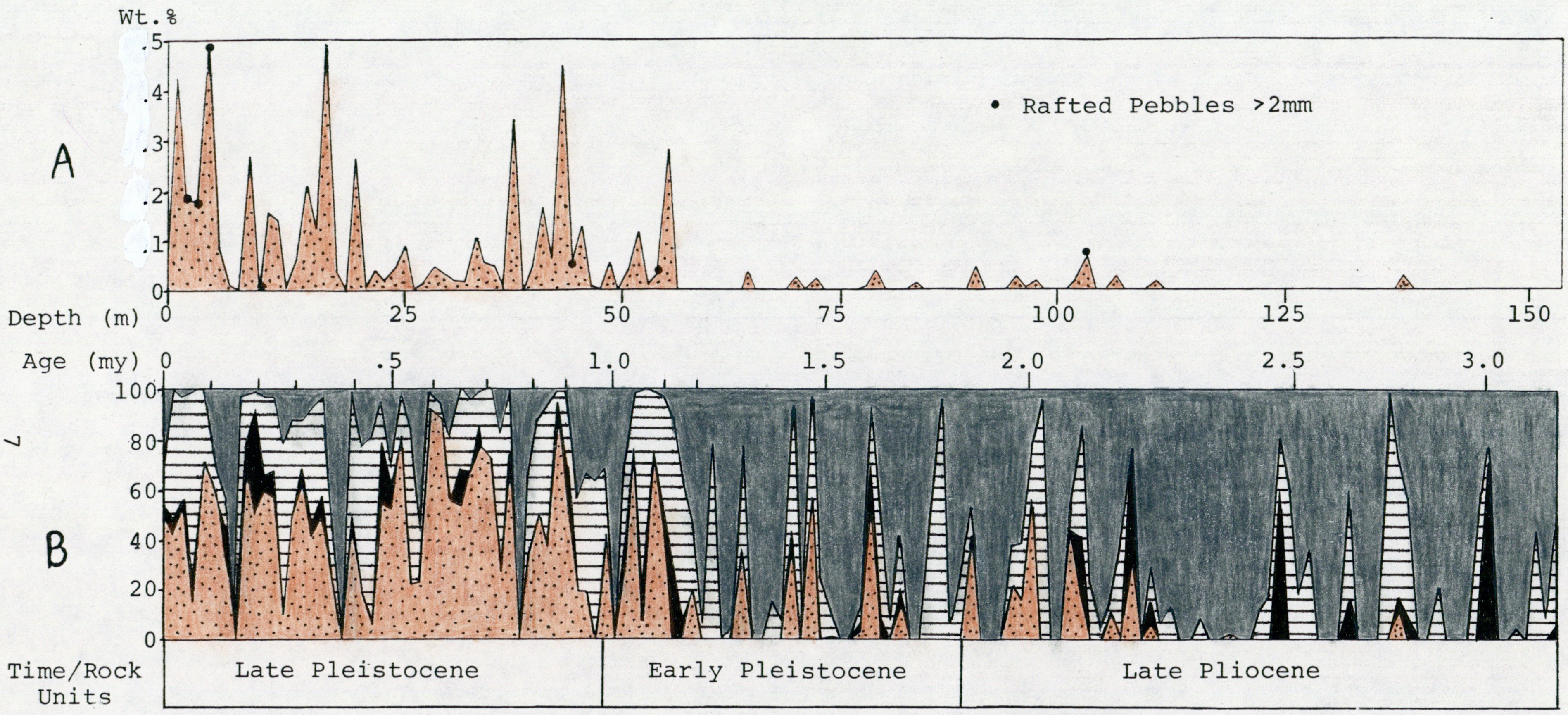
The criteria for determining ice rafted origin are not well established. Kent et al. (1971) consider all non-biogenic grains $>250\mu$ to be of ice rafted origin. They believe windblown material could not travel far from its source, and cite as evidence that 99% of the particles in the volcanic ash layers found in the sediments are less than 88μ (from Ninkovich et al.). Conolly and Ewing (1970) found that airborne contemporaneous volcanics were a major contributor to the sediments in the $>62\mu$ fraction (Fig. 4C). They believe the source area for the airborne volcanics was the Aleutian Islands which are due north of the area sampled by Kent et al. (1971). Site 580, which lies within the area sampled by Conolly and Ewing (1970) is farther west (Fig. 1). If Conolly and Ewing (1970) are correct about the source of the volcanics, there should also be significant amounts of airborne volcanics in the area Kent et al. (1971) studied. The Gulf of Alaska study by von Huene et al. (1976) makes no mention of the presence of volcanics.

In the Site 580 cores, abundant amounts of ash $>250\mu$ as well as what were identified as volcanic lithic and mineral fragments (plagioclase and other minerals, some with bits of vesicular glass welded to them) were found. Ash was recognized as light colored highly porous rounded pumice, vesicular clear, black, and reddish-orange glass, clear fragments exhibiting conchoidal fracture, and glass shards. Much of the iron-rich black and orange glass is magnetic. While the possibility of glacial rafting as transportation for these is not discounted, their abundance in the absence of IRD in pre-glacial periods (Fig. 2B) suggests that they were airborne.

Conolly and Ewing (1970) believe the majority of the rafted material adjacent to Site 580 consists of altered volcanic sediments with minor amounts of continental sedimentary and igneous rocks. They differentiate between older rafted volcanics and those deposited contemporaneously by alteration. The rafted volcanics have devitrified and suffered secondary alteration to low grade metamorphic minerals, such as epidote, albite, prehnite, and pumpelleyite.

The method used for separating IRD from volcanic lithic fragments at Site 580 was based on surface texture. Fresh, angular fragments were identified as volcanic, and assumed to be deposited contemporaneously due to lack of any indication of weathering or transport. Rounded, abraded, and weathered fragments were identified as IRD. The transported sediments appeared to consist of minerals similar to the volcanics, along with quartzite, quartz, mafic rocks, and greywackes.

However, farther east in the Gulf of Alaska, von Huene et al., (1976) found that more than 50% of the IRD shows no signs of intergranular collision and less than 5% show any glacial faceting. The source area is presumed to be the Malaspina Glacier, and they believe rock falls from the glacial valley walls are the largest source of detritus. Hence, while ultimately some size criteria can probably be assumed as too large for wind and current transportation, identifications of 'rafted grains based on textural considerations must be evaluated with care.



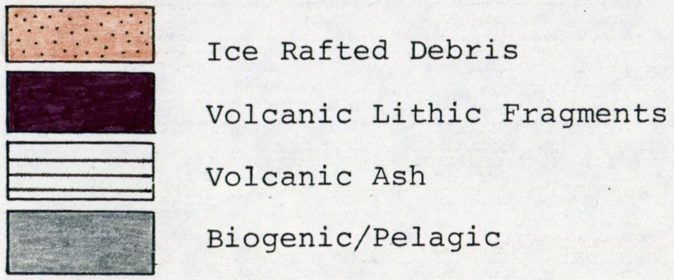


Figure 2. Site 580

Graph A - Wt.% IRD in Total Sample

Graph B - Wt.% Components in 250μ-2mm Fraction

DATA CALCULATIONS

The $>250\mu$ fraction of the samples were examined under a binocular microscope. Samples were evaluated by counting 200 grains (sample size permitting). Since grain size varied, approximations were made to obtain relative volumes. Granules and pebbles >2mm were removed and weighed separately. Some samples contained fairly indurated mudballs, consisting of siliceous muds, diatoms, and radiolarian fragments $<250\mu$. These were counted and corrections made to eliminate their weight from the data. Densities were determined by weighing equal volumes of the different components, then calculating density by making corrections for estimated packing. 30% void space was assumed for the biogenic components, and 55% for the others.

	Density
Biogenic	.180
Ash	1.160
Volcanic/IRD	2.778
Mud	.933
Fe-Mn Nodules	3.600

The following three steps were then used to calculate data:

(1) Convert Volume% to Wt.%

Sample Core	Total Wt.	Wt. 250μ-2mm (with mud)	Wt. 250μ-2mm (corrected)
1-1 (20-22)	6.3850g	.0183g	.0075g

	Volume%		Density		Wt'		Wt' Total w/o mud				Wt.% IRD in 250μ-2mm
ASH	2.0	x	1.160	=	2.320	÷	25.766	=	.090	=	9.0%
VOLC	.5	x	2.778	=	1.389	÷	25.766	=	.054	=	5.4%
IRD	4.5	x	2.778	=	12.501	÷	25.766	=	.485	=	48.5%
BIO	53.0	x	.180	=	+ 9.556	÷	25.766	=	.371	=	37.1%
					25.766 Wt' Total w/o mud						
MUD	49.0	x	.933	=	+37.324						
					63.090 Wt' Total with mud						

(2) Correct Wt. fraction to eliminate mud wt.

$$.0183\text{g} \begin{pmatrix}\text{Wt. } 250\mu\text{-2mm} \\ \text{with mud}\end{pmatrix} \times \frac{25.77 \text{ (Wt'Total w/o mud)}}{63.09 \text{ (Wt'Total with mud)}} = .0075\text{g} \text{ (Wt } 250\mu\text{-2mm)}$$

(3) Calculate Wt.% of IRD in total sample

$$\frac{.0075 \begin{pmatrix}\text{Wt.} \\ 250\mu\text{-2mm}\end{pmatrix} \times 48.5 \begin{pmatrix}\text{Wt.\%} \\ 250\mu\text{-2mm}\end{pmatrix}}{6.3850 \text{ (Total Wt.)}} = .057\% \text{ IRD in Total Sample}$$

ANALYSIS OF DATA

In the study by Conolly and Ewing (1970) the weight of the IRD in the >62μ-size fraction was plotted as wt.% of that size fraction. They used relative peaks in these graphs as indicators of intensity of glaciation. In deciding how to evaluate the data obtained from Site 580, I encountered several problems with this approach.

The total weight of the samples averaged 7 grams, and the 250μ-2mm fraction ranged from 0-.07 grams. Sometimes the very light fractions with minimal amounts of IRD have a relatively large wt.% of IRD due to the absence of any other sediments in that size range. When graphed as wt.% of the size fraction there were sometimes large peaks based on what were only 2 or 3 grains. In other samples representing the same amount of time there was a larger number of grains, but due to the presence of other sediments, a smaller wt.%. For instance, a large influx of airborne volcanic ash could easily "mask" samples containing large quantities of IRD. Obviously more 250μ-2mm IRD was actually transported in these periods than in the small samples where only 2 or 3 grains were counted, but the statistics as analyzed didn't reflect this.

In order to sample one size range and use the relative weight percents of the components in that size range as representative of some overall property of the sample as a whole, a big assumption must be made. That assumption is: there exists in one size fraction the same proportion of component abundances that would be obtained in other size fractions. If this assumption is not true, analyzing different size fractions will give different results, and the true relationships of the components cannot be determined unless the entire sample is analyzed. By using <u>relative</u> abundances in the $>63\mu$ fraction as representative of intensity of glaciation, I believe Conolly and Ewing (1970) imply that the non-IRD components in that size fraction are some constant against which the relative influxes of IRD can be measured.

The marine sediments under study have four different origins: (1) lithic debris transported to sea by floating glacial ice,(2) volcanic ash and lithic fragments carried by winds (some may also float out), (3) slow pelagic sedimentation of fine clays and silts, and (4) biogenic/pelagic precipitative sedimentation consisting chiefly of microorganisms and ferro-magnesium micronodules. None of the depositional mechanisms are related to the others (with the possible exception that cold temperatures may affect both glaciation and biogenic activity). Therefore, the relative abundances or sparsities of the non-IRD sediments within the size fraction would only dilute the data without offering any real comparison.

Therefore, I do not think the assumption of constant component proportions between different size fractions can be made, or even that the proportions of a single size fraction would offer a valid comparison at different time periods. At Site 580, much variety was observed in both the weight and components of the 250μ-2mm fraction. Events like the flourishing of a large species of radiolarians over a smaller species, or the precipitation of ferro-magnesium micronodules would superimpose their own patterns over the glacial activity pattern. I believe the only constant that it would be valid to compare abundances of IRD against would be time.

The rate of sedimentation as determined by paleomagnetic data and biostratigraphy was a remarkably constant average rate of 46.5 meters/million years at Site 580 (Heath, G.R. , 1983, unpublished). These rates were constant both in the presence and absence of glacial rafting. If the 250μ-2mm size fraction of IRD is representative of the total amount of IRD in the sample, then the actual weight of the erratics can be compared against the total weight of the sample as a function of the quantity rafted in a given time period. Therefore it would be meaningful to express the 250μ-2mm IRD wt.% of total sample as an indicator of glacial activity with comparison to other samples.

The next assumption that must be made is that the IRD in the 250μ-2mm size fraction is an indicator of the total amount of IRD in the sample, and that examination of other size fractions would not randomly amplify or dampen the results. There is some evidence that it may be representative.

Briggs and Kuhn (1969) studied glacial sediments in the northeast Pacific and found them to consist of roughly equal parts of sand, silt, and clay. In IRD in the Gulf of Alaska, von Huene et al. (1973) found strong correlations between the sand-sized and pebble fractions. Kent et al. (1971) in their north Pacific studies also believe that due to the poorly sorted nature of glacial marine sediment, variations in the wt.% of the >250μ fraction can be used as an index to the variation in the amount of ice rafted material in each sediment core.

Some common sense must be used in these assumptions. Although glaciers are competent enough to transport any size fraction with equal ease, what is actually transported depends on the source. A glacier scouring across a large lake bed is unlikely to transport anything but fine silts and clays and would not show any correlation between coarse and fine sediments. However, difficulties in recognizing features diagnostic of glacial rafting in fine sediments probably limits us to the approach of examining only the coarser fractions.

When sedimentation rates are constant, I believe that using the wt.% of the IRD in the total sample is a valid method of comparison. In Figure 2 two methods of graphing the data are shown. Graph B uses Conolly and Ewing's (1970) method of plotting the wt.% of the various components of the 250μ-2mm size fraction. In Graph A, the wt.% of the IRD in the total sample is plotted. Overall, the different approaches in Fig. 2 yield similar peaks except in the period between .4 and .7 million years ago. Graph B (IRD wt.% - size fraction) indicates an intense period of rafting, while Graph A (IRD wt.% - total sample) shows a reduction in glacial transport. For the reasons already discussed (which will be elaborated on), I believe Graph A is more valid. The analysis method of IRD wt.% of total samples will be the one referred to in comparison with other indicators of glacial activity.

Note that in Graph A, the IRD wt.% represents a very small percent of the total sample. The largest peak represents .038g. in a sample of 8.4g. Site 580 lies just north of the southernmost limit of glacial rafting as established by Conally & Ewing (1970), Griggs and Kulm (1969), and Kent et al. (1971). This accounts for the paucity of IRD.

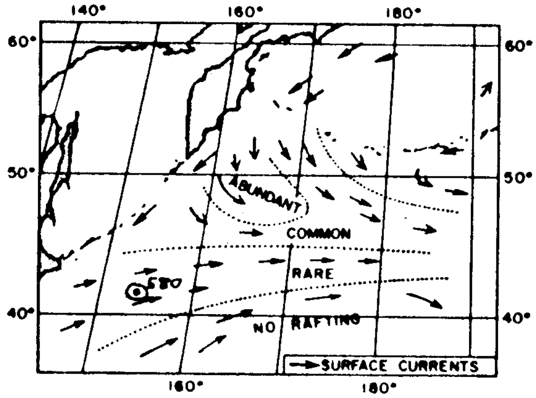


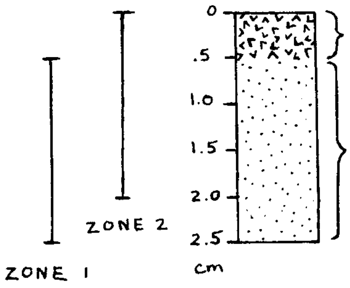
Figure 3. Distribution of ice rafted debris in the northwest Pacific showing location of Site 580. (Conolly and Ewing, 1970)

Sample size is normally thought of as indicating the total number of population elements in a sample. More faith is generally placed in estimates obtained from large samples than small ones. It stands to reason that the further from the glacial source, the greater the opportunity for random factors to influence IRD sedimentation rates.

The samples from Site 580 are intervals of 2 cm taken approximately 1 meter apart. Assuming a "constant" rate of sedimentation, each sample represents about 430 years of sedimentation. The gap between samples is approximately 21,070 years. Although sedimentation appeared constant overall, numerous layers of ash ranging up to 18 cm thick occur in this area. The average size of the ash is about 5.4 ϕ (medium silt) (Horn et al., 1969). Samples from the ash concentrations were not examined in this study, rather they are mentioned here to recognize the sometimes episodic nature of deposition, as well as the magnitude of "dilution" the IRD data might experience as the result of a high influx of sediments.

Imagine the only sedimentation in a given spot in the $>250\mu$ range to be the result of a steady flux of glacial ice drifting above it, melting and dropping IRD at a constant rate. "Normal" pelagic sedimentation $<250\mu$ also proceeds at its average constant rate, these ideal conditions prevailing for 429 years. During the 430th year, volcanic ash and lithic fragments rain down upon the spot, depositing .5 cm in a very short time. If sedimentation returns to its average rate, the rapid influx would not be noticeable.

Consider this simplified hypothetical sample as an illustration of how a very small scale fluxuation in rate of sedimentation could have a profound effect on data, and how the effect varies according to method of analysis:



.5 cm volcanic layer deposited 430th year

429 years of constant sed. rate of <250μ sediments with constant sed. rate of >250μ IRD

For simplicity assume uniform density of all components and total weight for a 2 cm sample is 7g.

(.5-2.5) interval contains 6.995 g. <250μ sediments
+ .005 g. >250μ IRD

(0-.5) interval contains 1.750 g. volcanics

		Wt.% IRD as Function of:	
		>250μ Fraction	Total Sample
Volcanic Influx >250μ	Zone 1	100%	.071%
	Zone 2	.21%	.053%
Volcanic Influx <250μ	Zone 1	100%	.071%
	Zone 2	100%	.053%

Zone 2 actually represents a 25% reduction in the time interval considered from Zone 1 which is our "ideal" sample. wt.% IRD - total sample mirrors this rate change (the sediments were actually deposited in 323 years), but in practice it would be difficult to determine which fluctuations are due to glacial advance and retreat, and which represent sedimentation rate fluctuations.

If this hypothetical sample were plotted on Fig. 2, the scale of Graph A would exhibit a 20% reduction of the peak, while on Graph B the peak would almost disappear. With the wt.% - size fraction analysis method, as long as the influx is >250μ (or outside any sample size one chooses to consider) the change in sedimentation goes unnoticed. But if it is in the same size range as the IRD being considered, erroneous conclusions would clearly be drawn. This rapid variation in influx could also be caused by proliferation of radiolarians, diatoms, or forams, as well as precitation of ferro-magnesian micronodules. The analysis that considers the wt.% IRD of the total sample shows a much smaller variation, independent of the sediment size of the rapid influx.

This is not to say that IRD wt.% size - fraction method is totally unreliable. As mentioned previously, larger sample populations are considered to be "more representative" than smaller ones. In this case, as the absolute quantity of IRD increases within a sample, its ability to overshadow "noise" due to fluctuating sedimentation rates increases.

In the hypothetical example given, increasing the IRD total 100 times (to .5g) shows the same relative change in data for the wt.% - total sample analysis (7.1%, 5.3%). In the wt.% - size fraction data for Zone 2, the 100% increase in IRD gives an enormous increase in wt.% - from .21% to 47%. Graph B would then show a 53% reduction in peak due to fluctuation of sedimentation rates.

Therefore, in zones of high IRD content the results of wt.% size fraction analysis would show discernable peaks. In areas where rafting is marginal though, the wt.% - size fraction graphs may fail to mirror actual relative amounts of accumulation of IRD between samples. Since data gathered in these areas is already subject to suspicion, (due to increase of random depositional factors and overall smaller populations), it is suggested that the wt.% (total sample) method of analysis is more reliable.

NORTHWEST PACIFIC

Conolly and Ewing (1970) analyzed samples from cores taken in the northwest Pacific near the same area as Site 580 (Fig. 4B). The samples were taken at intervals of 10 to 30 cm from cores up to 17 meters long. The oldest sediments sampled are 700,000 years old. They studied the $>62\mu$ size fraction. Their description of the components of the sediments appear to be consistent with what I observed.

Looking at Figures 4A and 4C, their correlation of IRD is good, becoming less consistent in the southern-most cores (approaching the furthest extent of glacial rafting). In Figure 4C is included the IRD wt.% - size fraction (solid line) for Site 580. This uses the same graphing method and scale, but shows much larger percentages of IRD. The IRD wt.% - total sample (using the top scale - dashed line) was also plotted. Neither approach shows any correlation with increases or decreases in rafting as indicated by the other graphs.

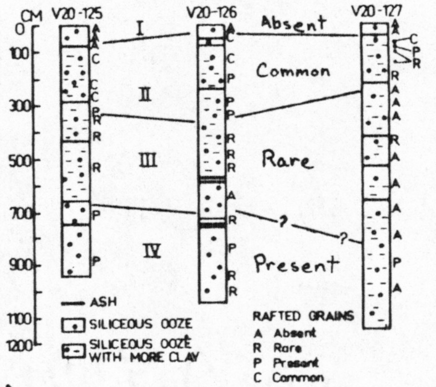
The size fractions are different, but this in itself should not be a cause for such a marked discrepancy. As was pointed out earlier, if information in one size fraction is to be considered a valid indicator of ice rafting, it should systematically be reflected in the other size fractions.

In Graph 4D I used the data available for Core V21-148 and plotted it with Site 580 as IRD wt.% - total sample. V21-148 is plotted against a wt.% scale 100 times greater than Site 580. There appears to be little correlation. In these simple graphs with few points the difference between the intervals sampled for the two cores is obvious. To compare what the graphs might look like if the intervals between samples had been equal, it's interesting to start at different data points on the V21-148 graph and see how connecting every other point, or every third point changes the shape of the graph.

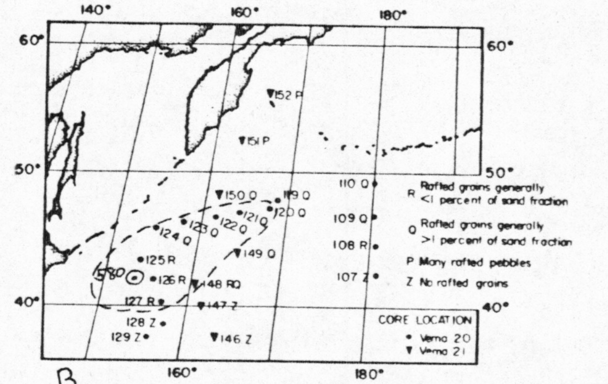
Information pertaining to the sample interval (or total sample weight) was not published. However for the data on Graph 4D, the mean wt.% of the entire >62μ sand fraction in the total sample for V21-148 is about 11%; for Site 580 it is 4.45% (3.8% 62μ-250μ, .4% 250μ-2mm, .25% > 2mm). Ash generally accounted for the majority of this higher sand fraction, but since V21-148 is located due east of Site 580 (further from the western arcs), it is not clear why it would contain such a greater quantity in the >62μ fraction.

Data was given for one of the eastern cores in Conolly and Ewing's (1970) study that appeared similar to Site 580. The quantities of >62μ sediments were in the same range as Site 580 for V20-109. The IRD wt.% - total sample for V20-109 ranged from 0 - .2% and its rafting maxima peaks are at 110 cm and 150 cm, which would correspond neatly to the Site 580 graph. However, Conolly and Ewing (1970) cite the palemagnetic evidence of Opdyke and Foster (1970) that show slower sedimentation rates at V20-109. They believe the rafting peaks correspond in time to the peak for V21-148 at 225 cm. Hence, there is no correlation at all with that core either.

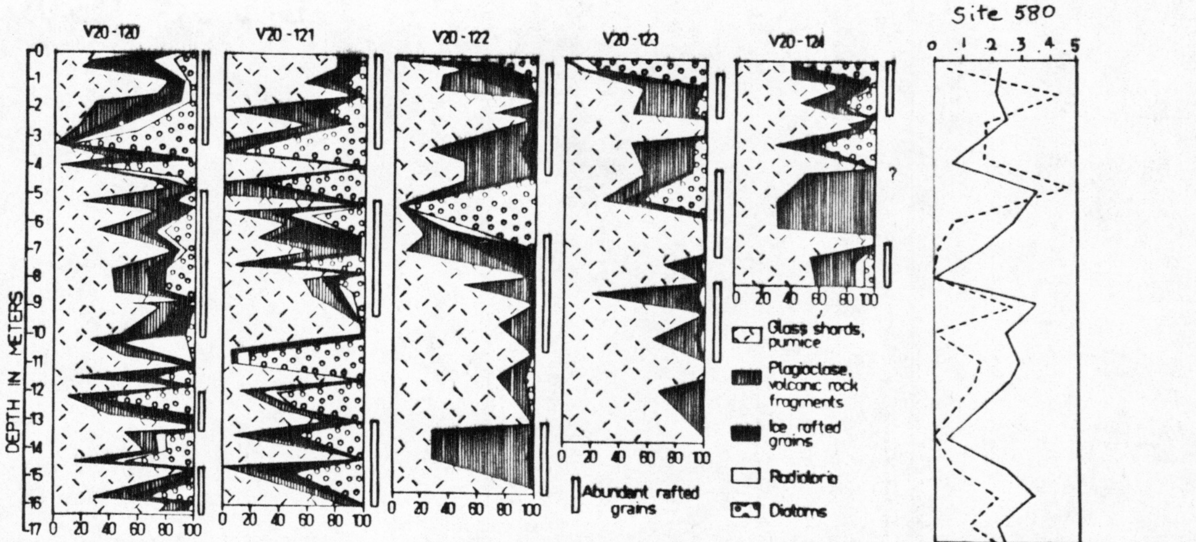
A possible reason for the lack of any correlation with other northwest Pacific cores is that the location of Site 580 was highly unfavorable for collecting a representative amount of IRD, and the minute amount present was influenced by random factors. If this is the case, it would not be very likely to correlate with any other data.



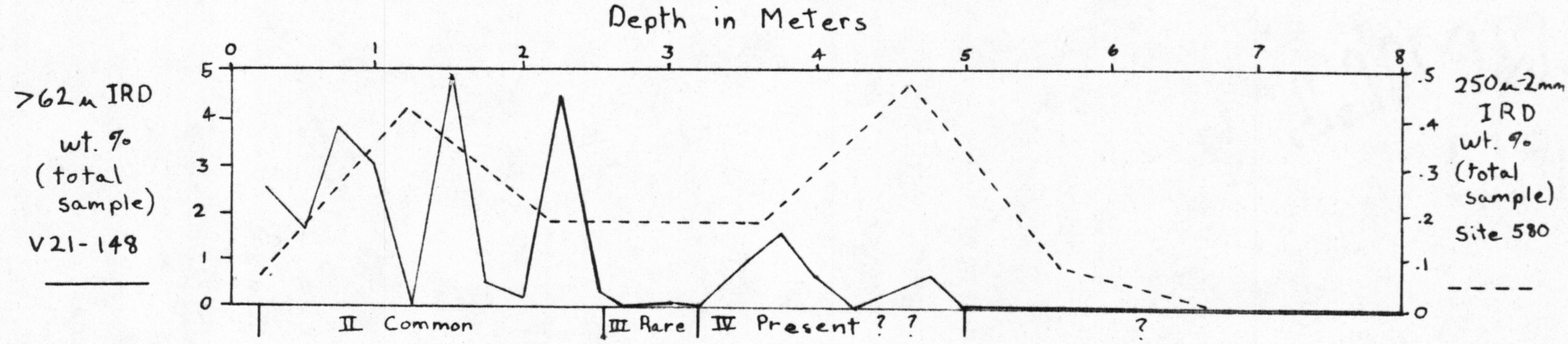
A. Relative amounts of ice-rafted grains found in the sand fraction (>62μ) of three cores from the northwest Pacific.



B. Location of deep-sea cores from the northwest Pacific Ocean sea floor.



C. Composition of the sand fraction (>62μ) in five *Vema* 20 cores from the northwest Pacific sea floor. Ice-rafted detritus occurs in three major zones.



D.

Figure 4. Comparison of Site 580 (250μ-2mm size fraction) with other cores from the same area, showing >62μ size fraction. (Graphs and data adapted from Conolly and Ewing, 1970)

NORTH PACIFIC

Kent et al. (1971) studied cores to the east of Conolly and Ewing's (1970) area in the north Pacific. The two areas overlap (Fig. 5). The interval between samples was 5-20 cm, and the sediments are up to 2.5 billion years old. Therefore, this is a much more detailed study than Site 580, and covers a more extensive time span than the samples analyzed by Conally and Ewing (1970).

Kent et al. (1971) describes some of the IRD in the >250μ fraction as consisting of abundant clear angular quartz grains, subangular to faceted igneous rocks, sandstones, siltstones, and metamorphic rock fragments. They mention the presence of volcanic glass and altered pumice in the >74μ size fraction, but make no mention of contemporaneous volcanics. Possibly the arcs of the Kurils, Japan, or Kamchatka were responsible for the abundance of contemporaneous >250μ volcanic minerals and lithic fragments at Site 580, not the Aleutians as Conolly and Ewing (1970) postulate. The surface currents and wind direction indicated by Horn et al. (1969) show that the distribution of fine ash around Site 580 is predominately from these western arcs.

Kent et al. (1971) looked at the 250μ-7mm size fraction, and cite their choice as being a favorable size to eliminate most radiolarians, diatoms, and windblown sediments. Although they aren't very specific about their methods, it appears that they used the dry weight of the 250μ-7mm fraction and did not calculate percentages of any components. (They give the impression that there are no other sediments besides IRD in this size range). Since the percentages of IRD that they plot range from 0 to 10%, I assume that they are plotting the wt.%

of the 250μ-7mm size fraction in the total sample. Their graphs are scaled to give equal intensity to maximum peaks, whether 2% or 10%. Because maximum wt.% would depend on distance from the source and small percents could be expected to be reliable down to some lower limit, the approach seems reasonable. Instead of plotting the percentages against a depth scale, in the north Pacific study they are plotted along a time scale as determined by paleomagnetic data and biostratigraphy for each core.

Interestingly, the core V20-109 sampled by Conolly and Ewing (1970) is also analyzed by Kent et al. (1971) to a much greater depth. In their study, the 250μ-7mm fraction wt.% - total sample ranges from 0 to 3%, which is a significantly higher value than the top 8 meters discussed previously. The coarse fraction of the sediments in Conolly and Ewing's (1970) study ranged from 0 to .8%. (This includes the 62μ-250μ fraction not used in the figure by Kent et al., 1971.)

The correlation of Site 580 with the data in Fig. 5 is very good. Many of the Site 580 low points correspond to lows in the other cores. More importantly, the peaks in the Site 580 data nearly always correspond to the peak points of the other cores. Since Site 580 was on the outer fringe of ice rafting, missing an indication of rafting would be explainable, even expected. But to have large peaks when there wasn't any indication of rafting going on elsewhere would probably be due to errors in identifying IRD or problems in determining ages for the samples. Also, since the intervals between samples was greater for Site 580, it would be reasonable to miss data points. There are however, peaks at .1 and .9 million years at Site 580, that are only confirmed in one of the other cores analyzed by Kent et al.

(1971). Five out of seven peaks though, appear to agree with the other cores.

The time interval between .4 and .7 million years ago in the cores looked at in the north Pacific study doesn't show any general overall increase in rafting. A few cores show a single peak during this time. This lends support to my theory that the wt.% - size fraction is less accurate, as this is the time period in which using that method of graphing the Site 580 samples gave what I felt were anomalously high percents.

The comparison of Site 580 results with terrestrial sequences (Fig. 6) is not very good. The generalized north Pacific core (Kent et al., 1971) has very strong peaks during major glaciations and corresponding lows during intergalcial periods. Why then, does the Site 580 graph which seems to correlate well with the original graphs, not show the same trends as the generalized curve? Part of the problem may be that the age controls on the data points from Site 580 are not as precisely located, and with the expanded scale this resolution difference becomes more visible.

Perhaps also, the "generalized" curve is really more of an "idealized" curve, with small liberties taken in determining which peaks are representative. For example, the peak at .6 million years corresponding to the Kansan Glacial is backed up by data that has 1 "full peak", 2 "half peaks", 1 "1/3 peak", and 3 "no peaks'. Overall however, the graph appears representative of the original graphs.

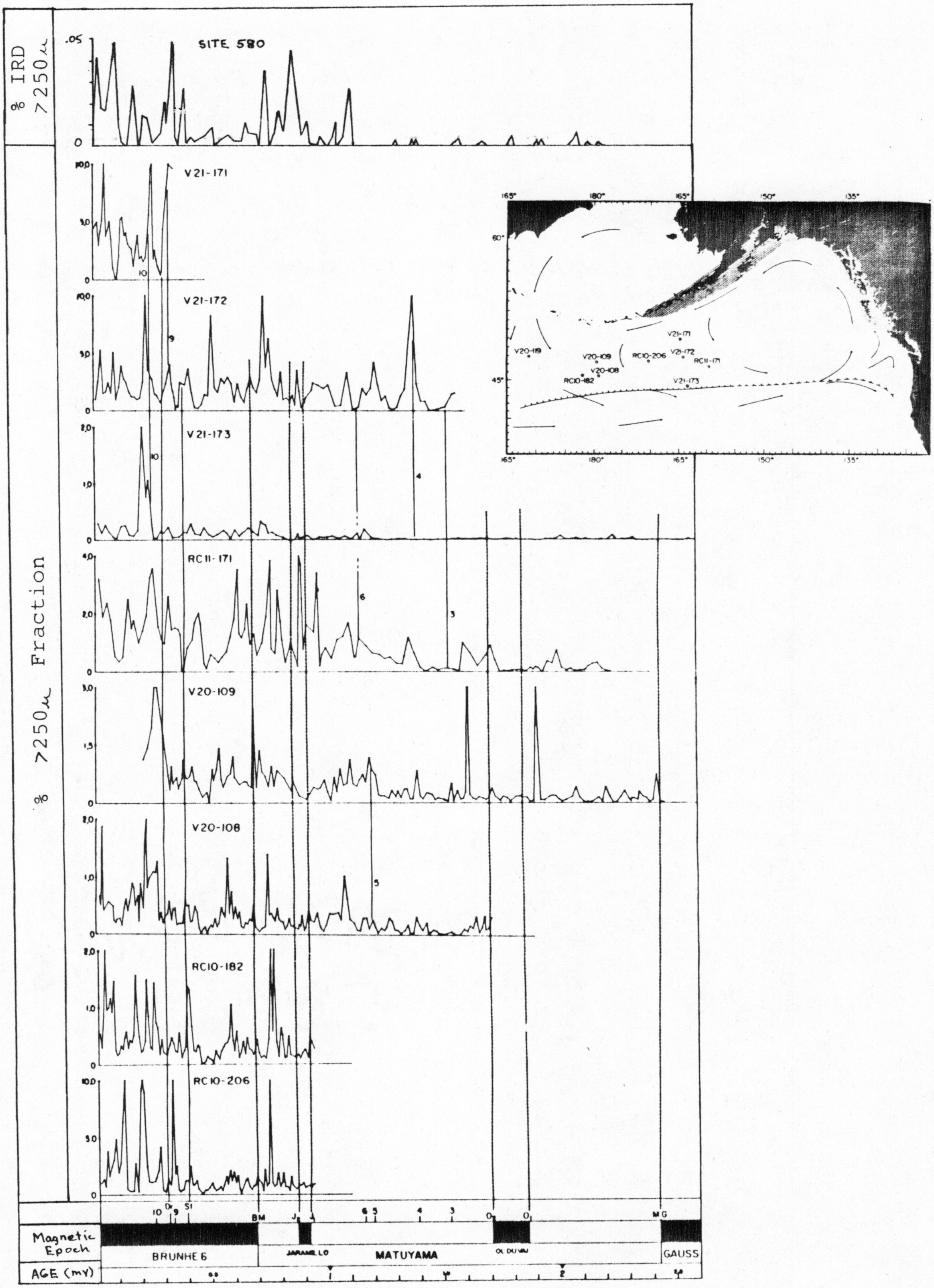


Figure 5. Site 580 compared with North Pacific cores studied by Kent et al. (1971). Inset map shows locations and present surface currents. Hachured line is southern limit of rafting as determined by Conolly and Ewing (1970) and Griggs and Kulm (1969). (Adapted from Kent et al., 1971)

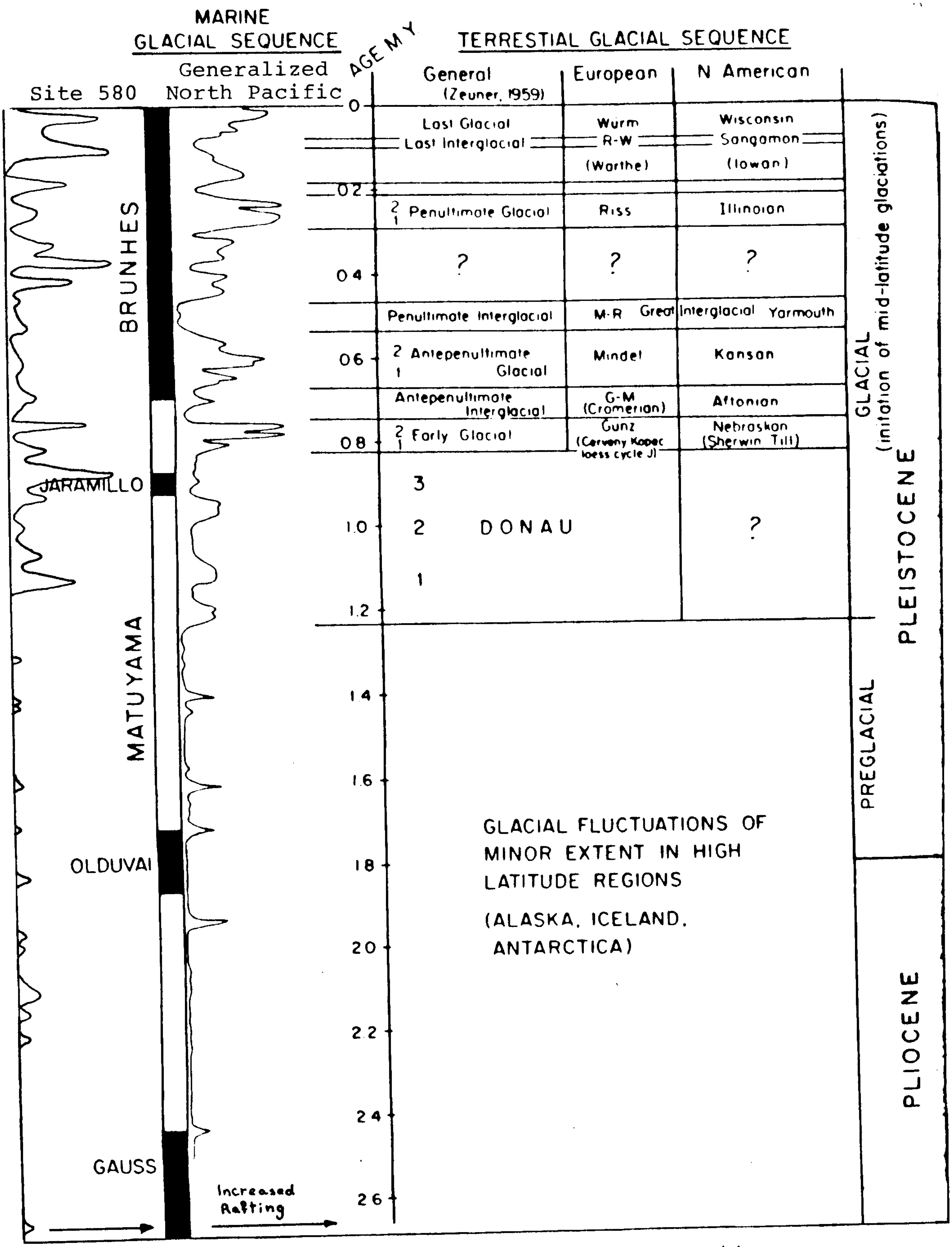


Figure 6. Correlation of terrestrial glacial sequences with Site 580 and generalized ice rafting curve from the North Pacific. Terrestrial sequence adapted from Zeuner (1959), Fling (1957), and Charles Worth (1957). (Graph adapted from Kent et al., 1971)

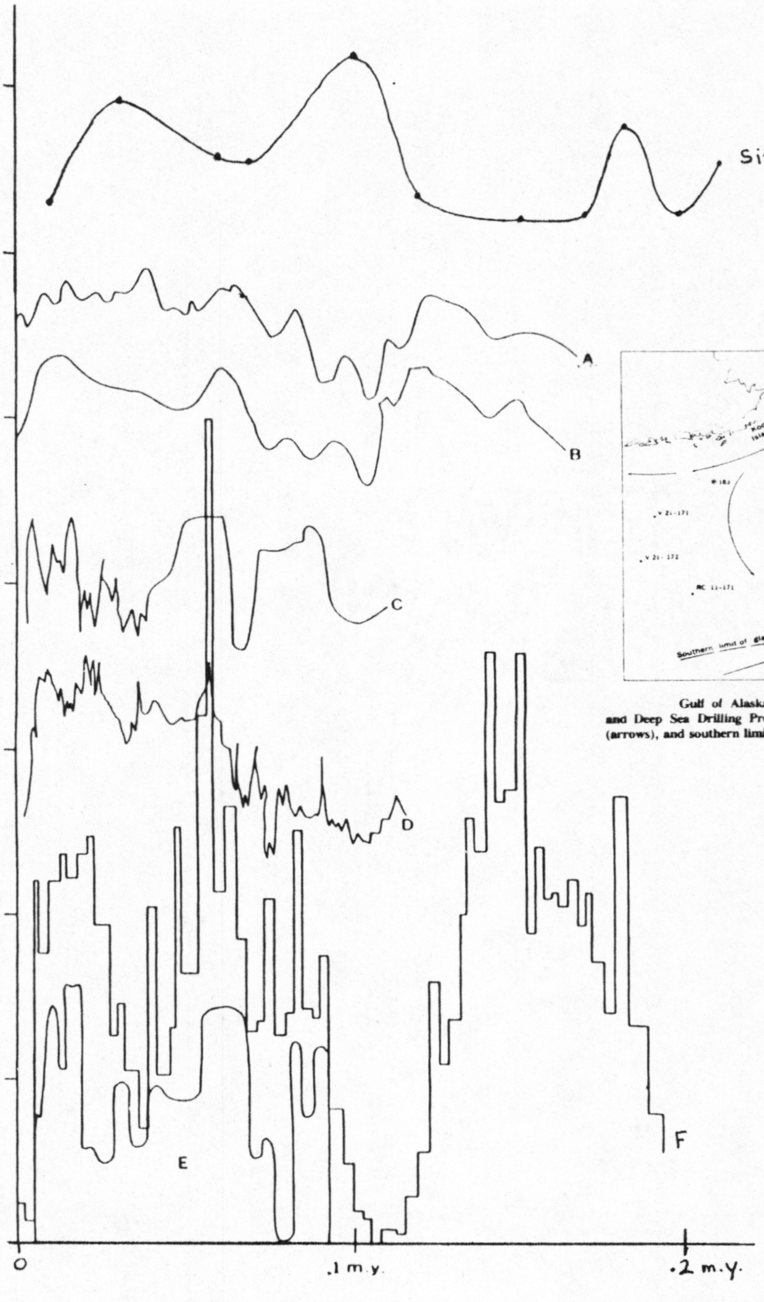
GULF OF ALASKA

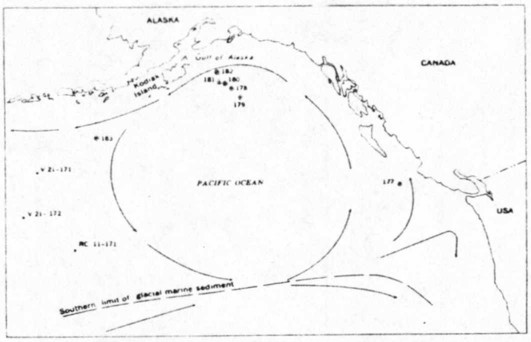
von Huene et al. (1973) studied cores 190 meters long from the Gulf of Alaska, which also coincides with the eastern portion of the area sampled by Kent et al. (1971). The investigation used sample analysis methods similar to those of Kent et al. (1971). The dry weight percent of a size fraction, not considering the presence of non-IRD components, was plotted against a time scale for the sediments. Presumably, in an area with a lot of rafting, the IRD could outweigh the other sediments in the size fraction sufficiently so they could be ignored for all practical purposes. The data as plotted ranges from 0 to 10%, the average being about 4%. Considering that the 250µ-2mm fractions in the Site 580 samples never were over 1.2%, the error caused by disregarding the non-IRD components is probably negligible.

The cores were close to the glacial source and contained numerous cobbles and pebbles larger than 200mm. von Huene et al. (1973) compared a graph of wt.% 250µ-2mm with one showing the number of pebbles (>2mm) per meter in the core, and found a good correlation between the two.

The resolution of this study was very high. Samples were taken from 20-50cm sections spanning ages of 1,700 to 2,600 years. The interval between the sample midpoints was about 3,000 years. These closely spaced data are in agreement with data from studies of paleo-ocean temperature, oxygen, isotope fluctuations, lake-level and sea-level fluctuations, and continental glacial evidence (Fig.7). The graph of Site 580 shows no correlation with any of this data. Similarly, the curve of Kent et al. (1971) shows no correlation with the Gulf of Alaska data. von Huene et al. (1973) note that the curve of Kent et al. (1971) has broader peaks and troughs because of the larger sample interval, the averaging that occurs during summation, and filtering due to a greater distance from the glacier source. These filtering properties are even more evident in the Site 580 core.

von Huene et al. (1976) believe that the proximity of high glacier-covered coastal mountains adjacent to the Gulf area sampled, make this area an especially sensitive indicator of climatic change. They believe there is evidence for a periodicity of glacial advance of 10,000 to 15,000 years. Naturally, no such periodicity is evident in the other core data due to the long time intervals between samples.





Gulf of Alaska showing location of Lamont-Doherty Geological Observatory (·) and Deep Sea Drilling Project cores (◎), direction of currents in the Alaska current gyre (arrows), and southern limit of glacial marine sediment (from Kent and others, 1971).

Figure 7. Comparison of Site 580 with other climate fluctation induced curves. Data points for Site 580 based on 10 samples from top 10.6 meters.

A - Kennett and Huddleston (1972); Gulf of Mexico, water temperatures inferred from microfossil assemblages. B - Emiliani (1971) using age scale of Broecker and van Donk (1970); Carribbean, oxygen isotope fluctuations. C - Smith (1968); southeast California, lake levels (based on Searles Lake). D - Dansguard et al. (1971); Greenland, oxygen isotopes. E - Morner (1972); northern Europe, glacial advances. F - von Huene et al. (1976); Gulf of Alaska, abundance of ice rafted detrius. (Data compiled by von Huene et al., 1976)

DISCUSSION

Throughout this paper I have mentioned various ideas and uncertainties as seemed pertinent to the topics under consideration. The main problems in trying to depict glacial changes over time by using core samples may be summed up by evaluating these 5 questions:

(1) What is the best way to treat the data to yield the most accurate assessment of the situation?

(2) Are the sample locations favorable to be representative of the general events as depicted?

(3) How accurate are the procedures that generate the data?

(4) Are the units being compared representative of equal quantities of time?

(5) Are the intervals between samples small enough that the samples reflect trends that may be interpolated?

In comparing the Site 580 data with other data, much of the discussion so far has focused on the first two ideas. The procedures that generate the data are harder to compare, because the articles cited aren't very specific about sampling procedures.

Ideally, in order to compare one study's results with those of a similar study, the procedures used should be standardized somehow. This is not the case in IRD investigations, probably because this type of research is fairly new. Factors such as fluctuating depositional rates, quantity and size of the fractions present, and condition of the core may require that the study be specifically tailored in order to get the best results. Hopefully, as research continues and core recovery improves, a standard systematic approach will evolve.

I believe that procedures I used to obtain IRD weight percentages are not very precise, but give "ballpark" figures that do reliably illustrate trends. Counting grains of such various sizes led to subjective estimates when grains above and below the average were counted. While I was consistent in my estimates (repeatability was generally within a few percent), that doesn't make them accurate. The density estimates I arrived at to convert estimated volume % to weight % may have also introduced error into the analysis. Kent et al. (1971) and von Huene et al. (1973) did not make similar estimates of the components. Conolly and Ewing (1970) did, and had vastly different values for component percents (Compare Fig. 2B with Fig. 4C) for the same area. As reluctant as I am to give too much weight to my absolute figures, I feel confident that my samples are in the range indicated, and wonder how Conolly and Ewing (1970) evaluated their samples.

Conolly and Ewing (1970) also had a far different wt.% of sand fraction than Kent et al. (1971). For the top 8 meters of core V20-109 their values for the $>62\mu$ fraction had a maximum of .8% of the total sample. Kent et al. (1971), while weighing a smaller fraction (250μ-7mm) had higher values of up to 3% for the bottom section of the core. Nearly all the cores show high rafting peaks within the first 8 meters, so the discrepancy in amount of coarse sand in the same core seems odd. Perhaps it's due to sedimentation rate fluctuations, but it seems more likely that the sampling procedures differed somehow.

The interval sampled, and intervals between samples were often stated in a confusing manner in the literature. Conolly and Ewing (1970) said they took samples every 10 to 30 cm, but list data tables showing sample depth intervals up to 100 cm. They make no mention of how much of the core they used for each sample. The best comparison I could figure out is this:

	Sampled Interval	Interval Between Samples
Site 580	430 years (2cm)	21,070 years (98cm)
von Huene et al. (1973)	3,000 years (20-50cm)	3,000 years
Kent et al. (1971)	(10cm)	10,000 years

The most visible difference between the graphs is the greater resolution gained from the smaller intervals between samples. The graph by Kent et al. (1971), and particularily the one by von Huene et al. (1976) show peaks based on a stepwise succession of data points (Fig. 7). In the Site 580 graph (Fig.2) most peaks are based on a single data point.

It's obvious that the shorter the intervals between samples, the better the results the data should yield. Ideally, sufficient sampling should give a smooth curve, where values extrapolated between the data points represent trends that actually occurred. One wouldn't hope to "pop in on the scene" every 10,000 years and really have a representative idea of what is going on.

In considering constant rates of sedimentation and the episodic nature that is observed, it might be concluded that this "episodicity" is so "constant" that the overall rates remain constant. A problem arises here -- what might be called an IRD "uncertainty principle." The shorter the time intervals that are sampled, the greater the detail that can be learned (looking at two 500 year time periods vs. a 1,000 year period). But the shorter the time intervals sampled, the less sure we can be that they represents the amount of time we think it does. Returning to the hypothetical example used before, the episodic change in sedimentation rate really meant a change in amount of time looked at. It isn't valid to compare IRD deposited in 320 years with the amount deposited in 430 years. When expressed as wt.% of equal samples with different sedimentation rates, time ceases to be a constant. As mentioned before, this episodic nature is not confined to thick ashfalls (which can be seen and avoided when sampling) but may be caused also by fluctuations in biogenic populations, ice rafting, chemical precipitation, and volcanics.

The sample method used by Kent et al. (1971) and von Huene et al. (1973), if I have interpreted it correctly, takes these fluctuations into consideration by sampling many consecutive intervals close together. They don't say whether they use the average values or use the most consistent figures. Although the interval over which they sample may span several thousand years, the reliability gained by sorting out "noise" caused by random IRD depositional events or episodic non-IRD deposition probably offsets the data loss due to averaging over the sample interval time span.

Clearly then, these sample intervals are superior to those used at Site 580. An enlightening future project would be to sample a single core using various sample intervals and intervals between samples to determine how the results vary, and the most efficient spacing of sample intervals for maximum resolution.

CONCLUSION

The investigation of Site 580 did not yield data that provides a good indication of glacial abundances. This lack of correlation with most other evidence is probably due to: (1) location of core near limit of glacial rafting, increasing random factors that obscure data (2) 21,070 year sample intervals that cannot show good resolution and (3) small sample interval which is sensitive to "noise" added to the data caused by small depositional rate fluctuation.

Site 580 did reflect the general broad trend of glacial advance, that is, a marked increase in rafting 1.2 billion years ago. The data appears to compare with that of Kent et al. (1971), but upon closer examination of many of the peaks based on a single point, do not show good correlation. This could be in part due to not having accurate enough age controls on the samples.

Sample Code	Depth (m)	Total Sample Wt. (g)	62 -250 Wt. (g)	250 -2mm Wt. (g)	2mm Wt. (g)	Wt. % in 250 -2mm Fraction: Ice Rafted Debris	Volcanic Lithic Debris	Volcanic Glass/ Pumice	Biogenic/ Pelagic	Wt. % Ice Rafted Debris in Total Sample
1-1 (20-22)	.21	6.3850	.2428	.0075	--	48.5	5.4	9.0	37.1	.058
1-1 (120-122)	1.21	5.1761	.3457	.0520	.0326 P	42.0	5.8	50.5	1.7	.424
1-2 (70-72)	2.21	8.0831	.0672	.0282	.0568 IP	51.7	4.0	41.5	2.8	.180
2-1 (32-34)	3.63	6.0069	.1285	.0706	.0618 IP	15.2	6.5	77.8	.5	.178
2-1 (130-132)	4.61	5.4708	.2034	.0380	.0068 I	70.5	--	29.5	--	.487
2-2 (80-82)	5.61	5.4795	.1060	.0077	--	58.1	--	11.5	30.4	.082
2-3 (30-32)	6.61	7.2294	.4103	.0016	--	33.4	8.4	14.0	44.2	.007
2-3 (130-132)	7.61	6.6435	.0889	.0014	--	--	--	6.1	93.9	--
2-4 (76-78)	8.57	9.3334	.6882	.0365	--	67.7	11.3	18.5	2.5	.265
2-5 (30-32)	9.61	5.7666	.1157	.0539	.0060 I	50.3	42.1	7.1	.5	.005
2-5 (135-137)	10.66	5.8702	.1222	.0155	.0059 P	59.1	6.4	31.9	2.6	.156
2-6 (40-42)	11.21	7.9738	.1586	.0194	--	56.9	10.0	30.0	3.1	.139
3-1 (45-47)	13.26	10.3405	1.2469	.0012	.0179 P	9.9	--	69.3	20.8	.001
3-1 (145-147)	14.26	5.6955	.0378	.0068	--	48.6	--	39.2	12.2	.058
3-2 (100-102)	15.31	5.4809	.0957	.0165	--	68.2	--	19.6	12.2	.205
3-3 (45-47)	16.26	6.1609	.0897	.0185	--	41.0	5.2	46.9	6.9	.123
3-3 (145-147)	17.26	6.9156	.1327	.0710	.0372 P	47.9	9.6	40.0	2.5	.492
3-4 (80-82)	18.11	8.9330	.5778	.0120	--	27.6	--	17.3	55.1	.037
3-5 (45-47)	19.26	6.2372	.1161	.0022	--	--	--	6.1	93.9	--
3-5 (110-112)	19.91	6.8040	.0993	.0395	--	44.8	4.0	50.8	.4	.260
3-6 (80-82)	21.11	7.8082	.0663	.0016	--	19.6	--	57.3	23.1	.004
4-1 (28-30)	22.59	5.7150	.3731	.0371	--	5.8	--	74.7	19.5	.038
4-1 (130-132)	23.61	6.4261	.1058	.0168	.0169 P	54.2	25.2	15.7	4.9	.014
4-2 (70-72)	24.51	7.4496	.0648	.0067	--	52.1	8.7	7.2	32.0	.047
4-3 (28-30)	25.59	7.0196	.0327	.0076	--	81.7	--	15.3	3.0	.088
4-3 (130-132)	26.61	6.3454	.0448	.0003	--	21.9	--	63.9	14.2	.001
4-4 (70-72)	27.51	6.2666	.0836	.0042	--	23.6	--	19.7	56.7	.015
4-5 (28-30)	28.59	6.7580	.0039	.0033	--	83.6	--	7.4	9.0	.045
4-5 (130-132)	29.61	7.1988	.0884	.0025	--	93.5	--	6.0	.5	.051
4-6 (74-76)	30.55	7.1475	.1815	.0024	--	55.6	--	25.1	19.3	.019
5-1 (28-30)	32.09	6.2964	.1033	.0021	.0120	53.5	14.5	32.0	--	.018
5-1 (135-137)	33.16	7.2595	.0760	.0110	--	67.4	--	29.0	3.6	.102
5-2 (70-72)	31.04	7.1793	.0013	.0050	--	76.8	7.8	14.7	.7	.053
5-3 (28-30)	35.09	8.5366	.2194	.0057	--	72.7	--	26.2	1.1	.049
5-3 (135-137)	36.16	8.9685	.2062	.0021	--	26.8	--	55.8	17.4	.006
5-4 (83-85)	37.14	9.1876	.1480	.0446	--	69.7	4.1	26.2	--	.338
5-5 (28-30)	38.09	7.1805	.0244	--	--	--	--	--	--	
5-5 (110-112)	38.91	10.6701	.4574	.0180	--	26.1	--	19.6	54.3	.044
6-1 (9-11)	41.40	7.6907	.6423	.0253	--	49.7	--	38.4	11.9	.164
6-1 (106-108)	42.37	6.5425	.1180	.0110	--	36.5	--	5.1	58.4	.061
6-2 (60-62)	43.41	8.4176	.3023	.0424	--	89.2	5.1	5.3	.4	.449
6-3 (9-11)	44.40	6.3375	.0654	.0069	.0434 IP	51.3	6.4	42.2	.1	.056
6-3 (106-108)	45.37	7.7787	.4104	.0052	--	19.1	--	35.8	45.1	.127
6-4 (52-54)	46.33	7.8231	.1342	.0032	--	18.9	--	47.4	33.7	.008
6-5 (9-11)	47.40	4.5556	.1457	.0252	--	--	--	63.1	36.9	--
6-5 (106-108)	48.37	6.4600	.0913	.0080	--	42.1	--	25.6	32.3	.052

P - Pumice
I - Ice Rafted Debris

Sample Code	Depth (m)	Total Sample Wt. (g)	62 -250 Wt. (g)	250 -2mm Wt. (g)	2mm Wt. (g)	Wt. % in 250 -2mm Fraction: Ice Rafted Debris	Volcanic Lithic Debris	Volcanic Glass/ Pumice	Biogenic/ Pelagic	Wt. % Ice Rafted Debris in Total Sample
6-6 (60-62)	49.41	6.9668	.3465	--	--	--	--	--	--	--
7-1 (13-15)	50.94	6.9419	.0917	.0105	--	27.3	11.4	27.5	33.8	.041
7-1 (115-117)	51.96	8.5231	.0727	.0130	--	75.3	--	23.6	1.1	.115
7-2 (86-88)	53.17	5.0451	.0581	.0064	--	6.9	2.3	90.6	.2	.009
7-3 (29-31)	54.10	6.9155	.0501	.0030	.0059 I	74.0	--	25.1	.9	.033
7-3 (110-112)	54.91	8.5486	.2203	.0571	--	42.2	12.1	42.8	2.9	.281
7-4 (56-58)	55.87	6.1240	.0535	.0022	--	--	32.6	56.1	11.3	--
7-5 (22-24	57.03	5.7911	.1036	.0011	--	--	7.7	56.0	36.3	--
7-5 (107-109)	57.88	6.1833	.0725	.0011	--	18.9	--	27.6	53.5	.003
8-1 (32-34)	60.63	5.1085	.3258	.0010	--	--	--	6.1	93.9	--
8-1 (110-112)	61.41	5.2687	.0497	.0011	--	--	--	78.4	21.6	--
8-2 (60-62)	62.41	5.7963	.0295	--	--	--	--	--	--	--
8-3 (24-26)	63.55	5.9779	.0208	.0027	--	--	--	6.1	93.9	--
8-3 (110-112)	64.41	8.4538	.4646	.0085	--	35.7	17.9	33.6	12.8	.033
8-4 (68-70)	65.49	6.1030	.0838	--	--	--	--	--	--	--
8-5 (24-26)	66.55	6.0041	.0085	--	--	--	--	--	--	--
8-5 (120-122)	67.51	5.2699	.0385	.0005	--	--	--	14.5	85.5	--
8-6 (60-62)	68.41	5.9713	.0650	.0022	--	--	--	6.1	93.9	--
9-1 (19-21)	70.00	5.7714	.1270	.0036	--	35.5	7.1	50.5	6.9	.022
9-1 (102-104)	70.83	4.4909	.0333	.0085	--	--	--	6.1	93.9	--
9-2 (56-58)	71.87	5.7029	.2533	.0023	--	57.0	14.2	25.7	3.1	.023
9-3 (19-21)	73.00	7.3804	.7435	.0216	--	--	--	24.4	75.6	--
9-3 (90-92)	73.71	6.7419	.0374	.0026	--	--	--	--	--	.001
9-4 (73-75)	75.04	4.1517	.0281	--	--	--	--	--	--	--
9-5 (31-33)	76.01	5.9761	--	--	--	--	--	--	--	--
9-5 (73-75)	76.54	6.5961	.0248	.0010	--	6.2	3.11	5.2	88.6	.005
10-1 (30-32)	79.61	9.5257	.0405	.0064	.0197 P	50.5	19.2	23.1	7.2	.036
10-1 (130-132)	80.61	7.2105	.0698	.0250	--	--	9.1	38.1	52.8	--
10-2 (80-82)	81.61	6.4675	.0148	.0083	--	--	--	6.7	93.3	--
10-3 (30-32)	82.61	7.2240	.0411	.0063	--	12.5	16.7	12.3	58.5	.011
10-3 (130-132)	83.61	7.1277	--	--	.0037 P	--	--	--	--	
10-4 (90-92)	84.71	7.9528	.0050	--	--	--	--	--	--	
10-5 (30-32)	85.61	6.2077	.0041	.0030	--	--	--	51.4	48.6	--
10-5 (145-147)	86.76	5.9363	.0611	.0341	--	--	--	96.3	3.7	--
10-6 (45-47)	87.26	6.3752	.0626	.0010	--	--	--	6.1	93.9	--
11-1 (30-32)	89.11	5.9711	.0889	.0244	.0014 P	--	--	34.3	65.7	--
11-1 (120-122)	90.01	6.8854	.0974	.0080	--	40.3	--	12.6	47.1	.047
11-2 (80-82)	91.11	7.0643	.0655	--	--	--	--	--	--	
11-3 (30-32)	92.11	8.3648	--	--	--	--	--	--	--	
11-3 (140-142)	93.21	7.8517	.1803	.0034	--	--	--	--	100.0	--
11-4 (80-82)	94.11	7.1798	.0786	.0081	--	21.2	--	15.5	63.3	.024
11-5 (32-32)	95.11	5.9834	.0988	.0017	--	15.9	--	23.2	60.9	.004
11-5 (110-112)	95.91	10.4624	.3665	.0027	--	56.3	--	23.6	20.1	.015
12-1 (40-42)	98.71	8.3496	.0892	.0028	.0099 P	--	--	96.6	3.4	--
12-1 (145-147)	99.76	5.6791	.1718	.0069	--	--	--	--	100.0	--
12-2 (90-92)	100.71	5.7011	.1096	.0043	--	--	--	--	100.0	--

P - Pumice
I - Ice Rafted Debris

Sample Code	Depth (m)	Total Sample Wt. (g)	62 -250 Wt. (g)	250 -2mm Wt. (g)	2mm Wt. (g)	Wt. % in 250 -2mm Fraction: Ice Rafted Debris	Volcanic Lithic Debris	Volcanic Glass/ Pumice	Biogenic/ Pelagic	Wt. % Ice Rafted Debris in Total Sample
12-3 (40-42)	101.71	6.3502	.0790	.0026	--	44.6	--	7.4	48.0	.018
12-3 (145-147)	102.76	8.7172	.1912	.0321	$.0386_{IP}$	18.0	22.5	44.0	15.5	.066
12-4 (90-92)	103.71	7.5967	.2762	.0098	--	--	--	22.6	77.4	--
12-5 (40-42)	104.71	8.8490	.1916	.0137	$.0022_{P}$	--	--	3.2	96.8	--
12-5 (105-107)	105.36	6.4924	.0666	.0147	--	11.4	--	2.7	85.9	.026
12-6 (90-92)	106.71	6.9715	.3422	.0158	--	--	--	38.6	61.4	--
13-1 (20-22)	108.01	8.5950	.4831	.0066	1.2183_{P}	32.9	39.5	4.1	23.5	.024
13-1 (120-122)	109.01	6.8894	.0932	.0084	--	--	--	--	100.0	--
13-2 (70-72)	110.01	8.0345	.1445	.0224	--	5.2	10.4	14.1	70.3	.014
13-3 (20-22)	111.01	5.5118	.1305	.0130	--	--	--	6.1	93.9	--
13-3 (120-122)	112.01	6.2226	.2637	.0134	--	--	--	13.3	86.7	--
13-4 (70-72)	113.01	6.5154	.1265	.0262	--	--	--	--	100.0	--
13-5 (20-22)	114.01	5.9482	.0174	--	--	--	--	--	--	--
13-5 (120-122)	115.01	7.5022	.0681	.0016	--	--	--	6.7	93.3	--
13-6 (70-72)	116.01	7.7332	--	--	$.0013_{P}$	--	--	--	--	--
14-1 (8-10)	117.39	5.0772	.0505	.0058	--	--	--	--	100.0	--
14-1 (108-110)	118.39	7.4128	.0635	.0113	--	1.5	--	--	98.5	.002
14-2 (80-82)	119.61	6.7802	.0350	--	--	--	--	--	--	--
14-3 (8-10)	120.39	5.1908	.0231	--	---	--	--	--	--	--
14-3 (108-110)	121.39	6.0920	.1543	.0053	--	--	--	9.9	90.1	--
14-4 (60-62)	122.41	7.7410	.0388	.0192	$.0207_{P}$	--	--	17.8	82.2	--
14-5 (8-10)	123.39	6.2751	.0102	.0026	$.1151_{P}$	--	60.2	20.6	19.2	--
14-5 (108-110)	124.39	5.4512	.0141	.0005	--	--	--	59.5	40.5	--
14-6 (60-62)	125.41	6.1672	.1069	.0015	--	--	--	18.4	81.6	--
15-1 (18-20)	126.99	7.4764	.0605	.0023	--	--	--	36.0	64.0	--
15-1 (114-116)	127.95	Seive broke - lost sample								
15-2 (61-63)	128.92	5.7706	.1570	--	--	--	--	--	--	--
15-3 (1-3)	129.82	4.6787	.0227	--	--	--	--	--	--	--
15-3 (101-103)	130.82	7.1745	.2843	.0027	$.0052_{P}$	--	14.7	60.0	25.3	--
15-4 (61-63)	131.92	4.9294	.0875	--	--	--	--	--	--	--
15-5 (1-3)	132.82	4.2623	.0416	--	--	--	--	--	--	--
15-5 (102-104)	133.83	5.2622	.0068	--	--	--	--	--	--	--
15-6 (52-54)	134.83	6.7943	.0133	--	--	--	--	99.5	.5	--
16-1 (10-12)	136.41	4.4749	.0956	.0110	$.0090_{I}$	11.4	5.7	57.0	25.9	.028
16-1 (110-112)	137.41	4.2843	.1325	.0078	--	--	8.8	47.8	43.4	--
16-2 (57-59)	138.38	5.4629	.2055	--	--	--	--	--	--	--
16-3 (10-12)	139.41	5.2898	.1297	.0084	--	--	--	21.1	78.9	--
16-3 (110-112)	140.41	5.3190	.1675	--	--	--	--	--	--	--
16-4 (57-59)	141.38	5.3263	.1364	.0059	--	--	--	--	100.	--
16-5 (10-12)	142.41	6.0206	.1647	--	--	--	--	100.	--	--
16-5 (100-112)	143.41	4.3039	.2955	.0075	--	--	--	--	100.	--
16-6 (57-59)	144.38	5.4186	.2036	.0108	--	--	--	51.2	48.8	--
17-1 (1-3)	145.82	5.7898	.1619	.0165	$.0027_{P}$	--	71.2	5.6	23.2	--
17-1 (103-105)	146.84	4.6055	.1770	--	--	--	--	--	--	--
17-2 (57-59)	147.88	4.6818	.2475	--	$.0041_{P}$	--	--	--	--	--
17-3 (1-3)	148.82	5.0332	.1017	.0076	--	--	--	4.1	95.9	--
17-3 (103-105)	149.84	5.5496	.2471	--	--	--	--	--	--	--

P - Pumice
I - Ice Rafted Debris

Sample Code	Depth (m)	Total Sample Wt. (g)	62 -250 Wt. (g)	250 -2mm Wt. (g)	2mm Wt. (g)	Wt. % in 250 -2mm Fraction: Ice Rafted Debris	Volcanic Lithic Debris	Volcanic Glass/ Pumice	Biogenic/ Pelagic	Wt. % Ice Rafted Debris in Total Sample
17-4 (57-59)	150.88	6.2654	.2475	.0080	--	--	--	42.8	57.2	--
17-5 (1-3)	151.82	6.3055	.3316	.0043	--	--	--	8.1	91.9	--
17-5 (106-108)	152.87	6.7028	.3092	.0094	.0081 P	--	4.2	49.1	46.7	--

P - Pumice

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